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Fire Dynamics in Northern Rocky Mountain Stand Types

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Abstract—In the Northern Rocky Mountains, fire growth and potential fire severity develop differently according to the type of vegetation. Grass, brush, and timber-dominated types respond to fire based on their unique physical characteristics and the sites they occupy. The fire dynamics of these three types are described, using examples, and their management implications are discussed.

Keywords: fuels, forest management, fire danger, fire control, fire behavior

Significantly different fire behavior patterns occur in timber stands of the Northern Rocky Mountains. Three of these types—grass/timber, timber brush, and timber/heavy down fuel—are used to conceptualize fire dynamics. The patterns show the contrast in fire behavior that can develop between stands on a seasonal basis. Fire dynamics describe how a stand's potential fire behavior develops through the fire season in response to increasing fire danger. Although ultimately influenced by fuel loading, size class distribution, fuel arrangement, fuel moisture, and continuity, fire dynamics can be more broadly ascribed to the stand's age, species composition, and structure in the context of habitat type. For instance, as fire danger increases, patterns of expected fire behavior in an open stand occupying a hot, dry site will contrast sharply with expected fire behavior in a closed canopy forest on a cool, moist site.

The range in fire behavior as exhibited by rate of spread and intensity can vary by orders of magnitude throughout the fire season. While we have methods for predicting some fire behavior, the methods are not comprehensive. For example, the national fire danger rating system provides a broad-based assessment of fire potential; but it is not structured to assess the range of fuel and weather conditions caused by elevation and aspect variations in mountainous topography. Managers need site-specific assessments along with the capability to anticipate probable dangers in fire conditions as the season progresses. Also, the fire behavior prediction methods developed for fires in surface fuels (Rothermel 1983) and for crown fires (Rothermel 1991) provide analytical tools, but these are designed for assessment over a few hours, not seasonally. Furthermore, for users who lack wide experience or are less familiar with the assumptions and limitations that underlie each model, consistently accurate results cannot be expected.

The best chance for success in fire behavior prediction requires a mix of fire experience with analytical modeling methods. But in situations where conditions are beyond the limits or outside the assumptions of the models, fire predictions must rely even more on intuitive judgments. Such judgments could be more easily made if managers know general patterns of fire behavior through a full range of burning conditions.

Extreme fire behavior can develop in any stand under severe conditions, but for purposes of discussion, we focus on the most common fire behavior observed in three stands and the patterns distinguishing each. The three examples in figure 1 compare relative differences in fire dynamics.

GRASS/TIMBER FUEL TYPE

A grass/timber fuel type on an open, hot, dry site (such as mature ponderosa pine/bluebunch wheatgrass, PIPO/AGSP) cures and dries quickly on the south aspects it usually dominates at low elevations.

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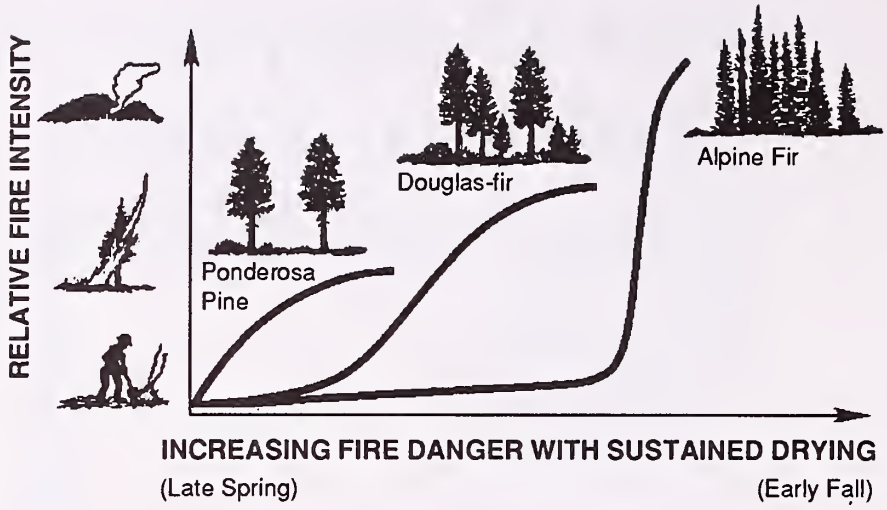

Figure 1—A comparison of expected fire behavior over a period of increasing fire danger for grass, brush, and timber-dominated examples.

Fires in the type described by this example are frequent. The curve in figure 1 shows that fire potential rises sharply early in the year and levels at moderate intensities. The predominant fine fuel component commonly dries quickly during late spring and, given an ignition, readily supports fire early in the burning season. However, the limited availability of fuel precludes fire behavior much above moderate. The fast-moving potential of fires in this type is often dangerous, but they collapse suddenly when burning conditions abate. Fires can usually be suppressed quickly.

TIMBER/BRUSH FUEL TYPE

A timber/brush fuel type on a warm, moist site (such as mature Douglas-fir/ninebark, PSME/PHMA) cures and dries more slowly than the grass type. Because the timber type described here usually occupies more shaded aspects at higher elevations and moisture is more abundant, the fuels take longer to dry. However, higher fuel loadings, deeper fuel bed depths, and more continuous arrangements often result in higher intensity levels than within the PIPO/AGSP example. The curve in figure 1 describing fire behavior responds more slowly but reaches a higher fire intensity level than the curve for the ponderosa pine.

TIMBER/HEAVY DOWN FUEL TYPE

A timber/heavy down fuel type on a cool, moist site (such as mature subalpine fir/menziesia, ABLA/MEFE) dries much more slowly than most other types. This stand usually occupies north aspects at high elevations. High fuel loadings and vertically continuous fuels are typical of mature stands. The curve in figure 1 describing fire dynamics in this stand characterizes the either/or dynamics of inconsequential or severe fire behavior that is common. Although ignitions in this type seldom result in fires of any consequence, when they do, successful fire suppression efforts frequently depend on a significant break in weather. Deep duff layers, concentrated heavy fuels, and a closed canopy result in persistent, difficult-to-suppress fires. Atmospheric influences and drought conditions can be especially critical precursors to high-intensity fires.

DISCUSSION

The fire behavior prediction methods (Rothermel 1983) and the associated fuel models (Anderson 1982) are best suited to the ponderosa pine example where the models better represent the fine fuels of grass and long needle pine litter found there. In Douglas-fir stands, the timber litter models are more appropriate, but the discontinuous distribution of dead and down material, particularly fine material, causes problems in accurate modeling. These problems are further aggravated in subalpine fir where the heavy accumulations of deep duff and decaying logs intermixed with surface litter represent a fuel condition beyond the assumptions of the fire model. The slow drying trend and rapid transition to severe burning conditions in those fuels are also difficult to estimate with fuel moisture models.

In our system, a curve labeled with a specific species designation in any of the three types does not necessarily mean that all stands of that designation

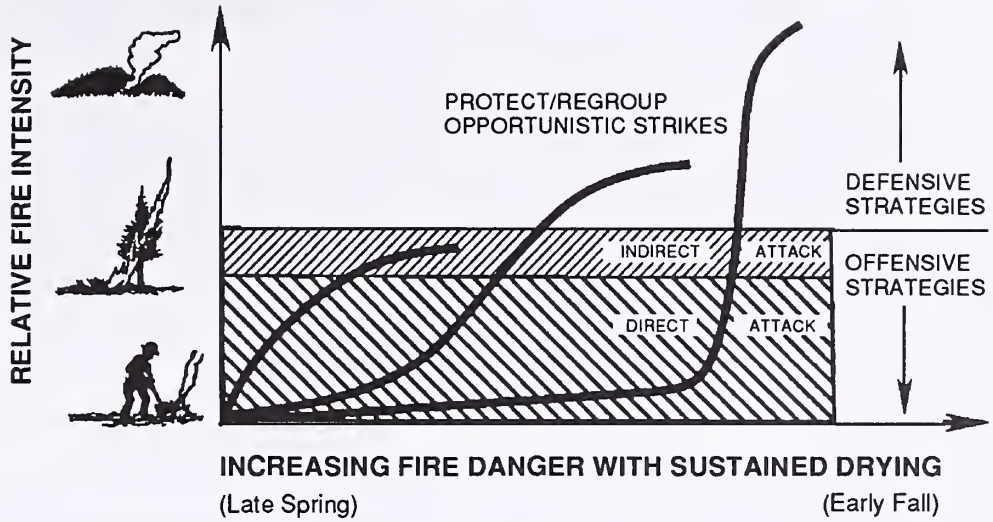

Figure 2—A comparison of tactical opportunities and limitations for grass and timber-dominated examples.

would demonstrate those fire behavior characteristics. For instance, a partially closed, multistoried ponderosa pine stand might be better represented by the Douglas-fir curve or a variation of it, instead of the ponderosa pine curve illustrated here.

MANAGEMENT CONSIDERATIONS

Suppression, prescribed burning, and fire behavior prediction can be evaluated on the basis of each example's fire dynamics curves. For example, figure 2 approximates fire control limits and related strategic and tactical considerations against expected fire behavior in the three examples. In ponderosa pine, an offensive strategy, employing direct or indirect attack, is applicable throughout its range of normal fire behavior. By contrast, the subalpine fir example shows that although offensive strategies are possible at the lower intensities, the transition to severe fire behavior is abrupt and necessitates rapid change in strategies from offensive to defensive—that is, protection oriented. The Douglas-fir example lies between these extremes in terms of suppression options.

Figure 3 compares the ponderosa pine and subalpine fir examples in terms of prescribed burning windows of opportunity. In the open mature

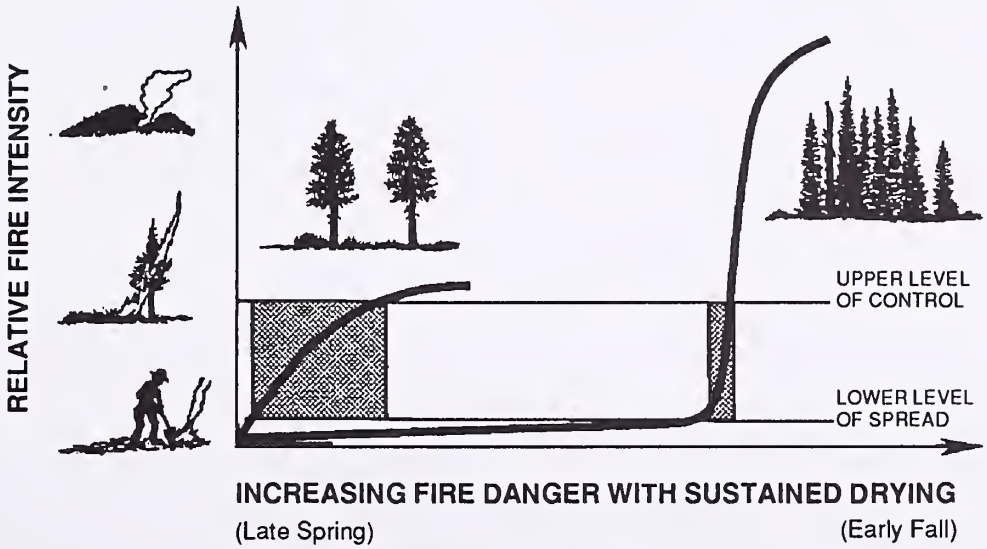

Figure 3—A comparison of firing windows between grass and timber-dominated examples.

ponderosa pine stand, wide prescribed burning windows are often available. However, in subalpine fir, the rapid transition to crown fire potential that occurs when the stand is dry enough to burn results in a narrow window of opportunity for prescribed burning.

Late in the spring, while fire is burning in ponderosa pine stands near the valley bottom, higher moisture levels may inhibit burning elsewhere at higher elevations. Later in the year, when subalpine fir stands start to exhibit extreme fire behavior, fires at lower elevations have likely been active for several weeks or even months.

Under drought conditions, in the grass/timber example, little seasonal difference would probably be evidenced in the onset of fire dynamics. By contrast, however, in the timber/heavy down fuel example, the curve describing fire dynamics would probably shift to the left, reflecting the stand's earlier season susceptibility to high-intensity fire because of dry, large-diameter fuels. During periods of drought, higher fire intensities can occur in any of the three examples but is more pronounced in those stands having heavier fuel loadings.

For severe fire behavior, the onset of crowning and the behavior of sustained running crown fire are two problems where atmospheric conditions must be considered as well as the fuels and degree of drought. Several recent publications provide new insight into the crown fire problem. Haines (1988) provides an index that identifies conditions under which crown fires may blow up (Byram 1954; Werth and Ochoa 1990). During summer drought, Beighley and Bishop (1990) describe conditions for the transition from a surface fire to crown fire in high-elevation stands as conditions become more severe during the day. Rothermel (1991) describes the types of crown fires that may develop and provides methods for evaluating the type of fire, the rate of spread, intensity, and size of wind-driven crown fires.

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